Project Report: Ultramafic–hosted Springs in Subduction Zones

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Project Progress

We are making progress in characterizing the chemical environment for microbial activity in the extreme environment of the serpentinite mud volcanoes in the Mariana forearc, which we believe to be an ancient, extreme environment for life on Earth, and possibly elsewhere in the Solar System, wherever water, carbon, and ultramafic rock (peridotite) like that of Earth's mantle are in contact. This environment produces some of the most alkaline water found in nature, with in–situ pH at 2°C as high as 13.1. Whereas serpentinization alone produces pH as high as 11.1 at 2°C, the much higher pH appears to result from a combination of two chemical reactions:

1) Oxidation of Fe–end–member olivine (fayalite) during serpentinization:

$$3Fe_2SiO_4 + 2H_2O = 2Fe_3O_4 + 3SiO_2(aq) + 2H_2$$

2) Methanogenesis, reacting carbonate ion with H2 produced in reaction 1:

$$4H_2 + CO_3^{2-} = CH_4 + H_2O + 2OH^-$$

Total alkalinity is conserved in reaction 2, but pH rises greatly as carbonate alkalinity is traded for hydroxyl alkalinity. Reaction 1 can certainly proceed inorganically, wherever water contacts peridotite, but Reaction 2 is probably microbially mediated. Reaction 2 provides methane that fuels Archaea within the shallow subseafloor of serpentinite mud volcanoes in the Mariana forearc. These extremophilic Archaea use sulfate to reduce this methane at pH 13.1, as documented by Mottl *et al.* (2003, *Geochem., Geophys., Geosystems* 4,11: 9009, doi:10.1029/2003GC000588):

3) Anaerobic oxidation of methane utilizing sulfate:

$$CH_4 + SO_4^{2-} + OH^- = CO_3^{2-} + HS^- + 2H_2O$$

Given the abundance of ultramafic rock on the terrestrial planets, including Mars, it is conceivable that these same reactions are possible in extraterrestrial environments, as well as on Earth.

Highlights

- Inorganic generation of hydrogen gas during hydration of mantle rock may fuel microbial life on other planets, as it does on Earth. This process has been demonstrated in serpentinite mud volcanoes in the Mariana forearc, on the floor of the Western Pacific Ocean, where it supports a community of Archaea.
- New team postdoc, Brian Glazer, has arrived and will begin working on this project.

Roadmap Objectives

- ***Objective No. 2.1:*** Mars exploration
- ***Objective No. 4.1:*** Earth's early biosphere
- ***Objective No. 5.1:*** Environment–dependent, molecular evolution in microorganisms
- ***Objective No. 5.2:*** Co–evolution of microbial communities
- ***Objective No. 5.3:*** Biochemical adaptation to extreme environments
- ***Objective No. 6.1:*** Environmental changes and the cycling of elements by the biota, communities, and ecosystems
- ***Objective No. 6.2:*** Adaptation and evolution of life beyond Earth